Supersolid phases in quantum gases

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The concept of a supersolid state is paradoxical. It combines the crystallization of a many-body system with dissipationless flow of the atoms it is built of. This quantum phase requires the breaking of two symmetries, the phase invariance of a superfluid and the translational invariance to form the crystal. We experimentally studied two forms of supersolids: i) a lattice supersolid, breaking a discrete translational symmetry. This bosonic lattice model features competing short- and long-range interactions, and we observed the appearance of four distinct quantum phases—a superfluid, a supersolid, a Mott insulator and a charge density wave. The system is based on an atomic quantum gas trapped in an optical lattice inside a single high-finesse optical cavity [1]. ii) Most recently, we succeeded in realizing a supersolid breaking a continuous translational symmetry. This symmetry emerges from two discrete spatial ones by symmetrically coupling a Bose-Einstein condensate to the modes of two optical cavities [2].

[1] R. Landig, L. Hruby, N. Dogra, M. Landini, R. Mottl, T. Donner, T. Esslinger, Nature 532, 476 (2016).

[2] J. Léonard, A. Morales, P. Zupancic, T. Esslinger, T. Donner, Nature 543, 87 (2017).